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Inventors: H. Hosokawa, M. Yamashita

Applicant: TATEISHI DENKI CO. LTD., Kyoto, Japan

Title of the Invention

Complex Optical Element

## SPECIFICATION

### 1. Title of the Invention

Complex Optical Element

### 2. What is claimed is:

(1) A complex optical element characterized in that on a grating element including a grating layer provided on a transparent substrate and a protection layer provided on the grating layer, one or more grating elements are provided on said grating element.

### 3. Detailed Explanation of the Invention

#### (a) Industrial Application Field

The present invention relates to a complex optical element including a stack of a plurality of grating elements.

#### (b) Prior Art

In known complex optical elements, e.g. known complex grating elements, grating layers are provided on front and rear surfaces of a glass substrate or two glass substrates each having a grating layer applied on a front surface are cemented together such that their rear surfaces are contacted with each other.

#### (c) Problems to be Solved by the Invention

In the above mentioned known complex grating element, the number of the substrates is limited to two. Therefore, its application is limited. Moreover, since the complex grating element has no flat surface portion, it could not be applied to another optical element to form an integrated structure.

Furthermore, there has been required a high NA Fresnel lens as an objective lens of an optical pick-up and a LD collimator lens. However, in the Fresnel lens, the higher NA (stop angle of a lens) is, the smaller a smallest period becomes. A relationship between NA and the smallest period may be expressed by the following equation:

$$A = \lambda / \text{NA}$$

wherein A denotes a smallest period and  $\lambda$  is a wavelength.

An objective lens for the optical pick-up should have NA not less than 0.45, and thus the smallest period is about  $1.7\lambda$ . Therefore, manufacturing accuracy becomes very strict and further there are problems that a manufacturing error might cause a decrease in efficiency and a generation of an on-axial aberration. When the period becomes smaller, a

deviation from a phase shift function (theoretical error) becomes large, and an efficiency is decreased. In this manner, in the Fresnel lens, it is rather difficult to realize a high NA lens having a high efficiency and a lower aberration. Moreover, since the Fresnel lens has a large off-axis aberration, and thus an alignment of optical axes becomes very difficult. If an off-axis aberration is limited not larger than 0.01 in a lens having NA of 0.45, an angular deviation must be restricted not larger than 0.016 (deg). However, this is very difficult (refer to Fig. 3).

A known LD collimator with a beam shaping faculty used in a light source of an optical disk device mainly for writing, is consisting of a high NA collimator lens 41 and a beam shaping prism 42 as illustrated in Fig. 4. Light emitted from a semiconductor laser light source 43 arranged near a focal point is converted into a parallel light beam by the collimator lens 41 and this parallel beam is shaped into a circular beam by the beam shaping prism 42. In this structure, the high NA collimator lens and beam shaping prism are expensive, and the LD collimator is liable to be large in size.

The present invention has for its object to provide a complex optical element, which can resolve the above mentioned problems, has a high NA and can be integrated with another optical element to form a unit structure.

(d) Means for Solving the Problem and Function

According to the invention, in order to attain the above object, a complex optical element has the following structure.

According to the invention, a complex optical element characterized in that on a grating element including a grating layer provided on a transparent substrate and a protection layer provided on the grating layer, one or more grating elements are provided on said grating element.

In the complex optical element according to the invention, the grating layer is formed on the surface of the transparent substrate and the protection layer (for instance, UV cured resin) is applied on this grating layer. Therefore, by providing a grating element on the protection layer, it is possible to realize a complex optical element having the two grating layers stacked on the other and at least one surface constitutes a flat surface which allows an integration (integration with another optical element). Moreover, when a protection layer having a flat surface is applied on one of the grating layers, a third grating layer may be provided on this flat surface of the protection layer. That is to say, according to the invention, it is possible to provide a complex optical element having three or more grating layers stacked each other. In this manner, various kinds of optical elements (for instance, a complex Fresnel lens) may be combined without a limitation of number, an applicable field can be widened by leaps and bounds. Furthermore, the complex optical element according to the

invention has a flat surface (the flat rear surface of the substrate), and therefore it can be easily integrated with another optical element.

In order to realize a lens having NA 0.45 by the complex optical element (complex Fresnel lens) according to the invention, when a two layer type (an integrated unit with two lens layers) is used, it is sufficient for a lens layer to have NA 0.24, and when a three layer type (a unit with three lens layers) is used, a lens layer is sufficient to have NA 0.16. Therefore, the smallest period of such a Fresnel lens can be large and a deviation from the phase shift function can be reduced, so that a very high NA can be realized, while its efficiency becomes large and an on-axis aberration can be suppressed. Moreover, since an off-axis aberration is small, a tolerance for the angular deviation can be increased, and therefore the alignment of optical axes can be performed easily.

(e) Embodiments

Figs. 1(A) and 1(B) are explanatory drawings showing embodiments of the complex optical element according to the invention. In the present embodiment, the optical element is constructed as a high NA complex Fresnel lens.

Fig. 1(A) illustrates an embodiment, in which a complex Fresnel lens is formed by two lens layers.

The Fresnel lens 1 includes optical element body 1a consisting of a glass (transparent) substrate 11, a Fresnel lens layer 12 formed on a top surface of the substrate, and a protection layer 13 applied on a top surface of the lens layer 12. A Fresnel lens layer 14 is provided on the protection layer 13 of the optical element body 1a. For instance, the lens layer 12 is formed by depositing an inorganic material ZnS on a mold (stamper) of the optical element by the vacuum thin film forming method (e.g. vacuum evaporation method), and then an UV curable resin is applied on the lens layer 12 to cement the glass substrate 11. By irradiating UV ray, the UV curable resin is hardened, and the assembly is removed from the stamper to form the lens layer 12 cemented to the substrate 11. Next, an UV curable resin is applied on the lens layer 12 with a constant thickness, and after making a surface of the resin flat, UV ray is irradiated to harden the resin to form the protection layer 13. Finally, the lens layer 14 is cemented onto the protection layer 13 in the manner explained above.

Fig. 1(B) shows the Fresnel lens having three lens layers stacked each other.

In the present Fresnel lens, after forming the two layer Fresnel lens shown in Fig. 1(A), a protection layer 15 is formed on the lens layer 14, and then a lens layer 16 is formed on the protection layer 15.

In the two-layer Fresnel lens shown in Fig. 1(A) as well as in the three-layer Fresnel lens illustrated in Fig. 1(B), a surface of the Fresnel lens on the side of the glass substrate 11 (the rear surface of the substrate 11) is flat, and therefore they can be easily integrated with another optical

element.

In order to obtain a lens of NA 0.45 with the aid of the Fresnel lens according to the invention, in the two-layer Fresnel lens (Fig. 1(a)), NA 0.24 is sufficient, and in the three-layer Fresnel lens (Fig. 1(B)), NA 0.16 is enough. Therefore, the minimum period can be large and a deviation from the phase shift function can be reduced, and thus it is possible to provide a high NA lens having a high efficiency and a small on-axis aberration. Moreover, since an off-axis aberration can be decreased and an allowance for the angular deviation can be increased, the axial alignment can be performed easily.

In conventional aspherical lenses, NA is limited to a value within a range from about 0.5 to about 0.6 owing to a curvature. However, since the Fresnel lens is flat, NA is not limited and can be increased without any limitation by making the multiple layer structure. For instance, if four Fresnel lens layers each having NA 0.24 are provided, it is possible to obtain a lens having NA 0.7. When such a lens is utilized as an objective lens in an optical pick-up, a spot size can be reduced by two times as compared with the known pick-up (NA 0.45), and a recording density on an optical disk can be increased by four times.

Fig. 2 is an explanatory drawing, in which a LD collimator with a beam shaping faculty is constructed by the above embodiment of the complex Fresnel lens.

In the present embodiment, the two-layer high NA Fresnel lens shown in Fig. 1(A) is arranged to be opposed to a LD chip 3 and a beam shaping grating 2 is cemented on the substrate side (flat surface) of the Fresnel lens. Diverging light emitted from the LD chip 3 is collimated by the high NA Fresnel lens, and collimated light is shaped into a circular beam by the beam shaping grating 2. Upon compared with conventional collimator (Fig. 4), the LD collimator with the beam shaping faculty of the present embodiment can be small in size, light in weight, cheap in cost and can operate stably. Particularly, a special advantage that an access time can be shortened in the optical disk can be attained owing to the light weight.

#### (f) Merits of the Invention

As explained above, in the present invention, in the grating element including the grating layer provided on the transparent substrate and the protection layer provided on the grating layer, one or more lens layers are stacked on the protection layer. Therefore, at least one surface can be a flat surface which can be easily integrated with another optical element, and it is possible to provide the high NA optical element including a plurality of lens layers.

In the complex optical element according to the invention, since any desired number of optical elements (grating elements) can be stacked each other, its application can be widened greatly. Moreover, in the case of

the complex Fresnel lens, it is possible to attain the high NA lens having a high efficiency and a small on-axis aberration. Since an off-axis aberration can be also reduced and an allowance for the angular deviation can be increased, the axis alignment can be performed easily. Furthermore, the optical element according to the invention can be easily integrated with another optical element, and thus a high integration can be improved and an optical device can be small and light. In this manner, the objects of the present invention can be achieved and superior merits can be attained.

#### 4. Brief Explanation of the Drawings

Fig. 1(A) is an explanatory drawing showing an embodiment of the two-layer type Fresnel lens, Fig. 1(B) is an explanatory drawing illustrating an embodiment of the three-layer type Fresnel lens; Fig. 2 is an explanatory drawing denoting a LD collimator with beam shaping faculty utilizing the embodiment of the Fresnel lens; Fig. 3 is an explanatory drawing representing a relationship between the NA of Fresnel lens and the angular deviation, while a wavelength is took as a parameter; and Fig. 4 is an explanatory drawing showing the known LD collimator with beam shaping faculty.

1: complex Fresnel lens, 11: glass substrate, 12, 14: Fresnel lens layer, 13, 15: protection layer

Applicant    TATEISHI DENKI Co. Ltd.  
Attorney     S. Nakamura

(Abridged English Translation of Amendment)

Amended

July 31, 1995

6. Subjects of the Amendment

"Title of the Invention", "Claims" and "Detailed Explanation of the Invention" should be amended in the following manner.

7. Contents of the Amendment

- (1) "Title of the Invention" should be revised into ---Optical Device---
- (2) "Claims" should be amended as described in separate sheets.

What is claimed is:

- (1) An optical device consisting of
  - a substrate having an optically functioning portion formed by depressions and protrusions on at least one surface of the substrate;
  - a layer provided on a surface of said surface of the substrate having the optically functioning portion, said layer being made of an optical material whose refractive index is different from that of the substrate and having a flat surface on a side opposite to the substrate; and
  - an optical element formed on said flat surface of said layer and having an optically functioning portion formed by depressions and protrusions.
- (2) An optical device consisting of
  - a substrate having optically functioning portions on both surfaces of the substrate, each of said optically functioning portions being formed by depressions and protrusions;
  - a layer provided on a surface of at least said optically functioning portion, said layer being made of an optical material whose refractive index is different from that of the substrate and having a flat surface on a side opposite to the substrate; and
  - an optical element formed on said flat surface of said layer and having an optically functioning portion formed by depressions and protrusions.
- (3) An optical device consisting of
  - a substrate having optically functioning portions on both surfaces of the substrate, each of said optically functioning portions being formed by depressions and protrusions;
  - a layer provided on a surface of at least said optically functioning portion, said layer being made of an optical material whose refractive index is different from that of the substrate and having a flat surface on a side opposite to the substrate;
  - at least one optical element at least one of its surfaces being flat; and
  - a layer provided between said substrate and said optical element and being brought into contact with said optically functioning surface of the substrate as well as with said flat surface of the optical element, said layer being made of a material whose refractive index is different from that of the optically functioning portion of the substrate.